



SEMICONDUCTOR LASER ELEMENT, SEMICONDUCTOR LASER MODULE,
FABRICATION METHOD THEREOF AND AMPLIFIER FOR OPTICAL FIBER

FIELD OF THE INVENTION

5 The present invention relates to a semiconductor laser
element, a semiconductor laser module, and the fabrication
method thereof, and an amplifier for optical fiber which
uses the semiconductor laser module. More particularly,
this invention relates to a semiconductor laser element
10 provided with two stripe structures which makes two laser
beams be emitted, a semiconductor laser module, and the
fabrication method thereof, and an amplifier for optical
fiber.

15 BACKGROUND OF THE INVENTION

Lately, needs for higher output power of excitation beam sources used for amplifiers for optical fiber has risen more and more along with developments of optical communications which uses high-density wavelength-division multiplex transmission methods.

And, recently, Raman amplifiers, rather than erbium-doped amplifiers for optical fiber which have been conventionally used as amplifiers for optical fiber, have been anticipated as units to amplify beams with further broad
25 bands. The Raman amplification is a method to amplify

optical signals, which uses a phenomenon where gains are
obtained at the side of a lower frequency by approximately
13THz from the excitation beam wavelength by guided Raman
scattering generated when excitation beams enter optical
5 fibers.

In the Raman amplification, it is required to reduce
the effects of shifts between the plane of polarization of
the signal beams and that of the excitation beams as much
as possible, as the signal beams are amplified in a state
10 where the polarization direction of signal beams and that
of excitation beams (pump beams) are the same. Therefore,
reduction in the degree of polarization (DOP) has been
performed by disabling the polarization of the excitation
beams (depolarization).

15 Thus, a method to perform polarization beam
combination of laser beams, which are output from two
semiconductor laser modules, with the same oscillating
wavelength by polarization beam combining couplers has been
known as a method to realize the higher output power and
20 depolarization of the excitation beam sources at the same
time, for example, as disclosed in the United States Patent
Publication No. 5589684.

Fig. 21 is an explanatory view which explains a
semiconductor laser device disclosed in the United States
25 Patent Publication No. 5589684. As shown in Fig. 21, a

semiconductor laser elements 60 and 61 may be fixed to the same wavelength, and laser beams with a fixed wavelength may be output from the optical fiber 67, as the fiber grating 66 is formed in the optical fiber 67.

5 Therefore, the conventional semiconductor laser device may be applied as an excitation beam source of an amplifier for optical fiber which requires higher optical output power, and, more particularly, as an excitation beam source of a Raman amplifier which requires low
10 polarization-dependence and wavelength stability.

 However, it is required in the conventional semiconductor laser device to arrange two chip carriers, which are provided with two semiconductor laser elements 60 and 61, on a base by soldering. At this time, more time
15 is required to position the semiconductor laser elements as it is required to be positioned, so that laser beams emitted from two semiconductor laser elements 60 and 61 perpendicularly intersect each other. As a result, fabrication time of the semiconductor laser module becomes
20 long.

 Moreover, it is difficult in a high temperature state to stabilize the intensity and degrees of polarization of laser beams output from the optical fiber as laser beams emitted from each semiconductor laser elements 60 and 61
25 are output in entirely different directions from each other

and there are effects of the warp of the package and so on in respective directions.

SUMMARY OF THE INVENTION

5 The object of the present invention is to provide a semiconductor laser element, a semiconductor laser module, and the fabrication method thereof, and an amplifier for optical fiber, wherein the semiconductor laser element is provided with two stripes to emit two laser beams which may
10 reduce time required to position the semiconductor laser element, and to center lenses and, at the same time, may stabilize the intensity, and the degrees of polarization of the laser beams output from the semiconductor laser element.

15 According to one aspect of the present invention, there is provided a semiconductor laser element, comprising; a first stripe which emits first laser beams and has a first active layer laminated on one part of an area in a semiconductor substrate; and a second stripe which emits
20 second laser beams and has a second active layer laminated in the other part of the area semiconductor substrate, wherein the distance between the center lines of the first stripe and the second stripe is 10 to 100 μ m.

 Another aspect of the present invention provides the
25 semiconductor laser element according to the above aspect,

wherein the first stripe and the second stripe are formed,
to extend parallel to each other.

Still another aspect of the present invention provides
the semiconductor laser element according to the above
5 aspects, wherein the distance between the insides of the
first stripe and the second stripe is 5 μ m or more.

Still another aspect of the present invention provides
the semiconductor laser element according to the above
aspects, wherein a first electrode formed on the upper
10 section of the first active layer and the second active layer;
a second electrode formed on the lower section of the
semiconductor substrate; and a heat sink at least a part
of which is formed with diamond are provided in, wherein
the first electrode or the second electrode is bonded to
15 the diamond of the heat sink.

Still another aspect of the present invention provides
the semiconductor laser element according to the above
aspects, wherein the wavelengths of the first laser beams
and the second laser beams are approximately 1200nm to
20 approximately 1600nm.

According to still another aspect of the present
invention, there is provided a semiconductor laser module,
comprising: the semiconductor laser element according to
from the first to the fifth aspects; a first lens where the
25 first laser beams and the second laser beams which have been

emitted from the semiconductor laser element are entered,
and are separated, so that the distance between the first
laser beams and the second laser beams is broadened; a
polarization rotating unit, wherein only one of the first
5 laser beams and the second laser beams, which have passed
through the first lens, enter the unit and rotates the plane
of polarization of the entered laser beams by a predetermined
angle; a polarization combining unit which comprises a first
port which the first laser beams from the first lens or the
10 polarization rotating unit enter, a second port which the
second laser beams from the polarization rotating unit or
the first lens enter, and a third port where the first laser
beams entered from the first port, and the second laser beams
entered from the second port are multiplexed and emitted;
15 and an optical fiber which receives laser beams emitted from
the third port of the polarization combining unit, and sends
the beams to the outside.

Still another aspect of the present invention provides
the semiconductor laser module according to the above aspects,
20 wherein the first lens is preferably positioned, so that
an optical axis of the first laser beams emitted from the
first stripe and an optical axis of the second laser beams
emitted from the second stripe are substantially in symmetry
with respect to the central axis of the first lens.

25 Still another aspect of the present invention provides

the semiconductor laser module according to the above aspects,
 wherein the polarization combining unit is a birefringent
 element, by which any one of the first laser beams entered
 from the first port, and the second laser beams entered from
 5 the second port propagate to the third port as an ordinary
 ray, and the other beams propagate to the third port as an
 extraordinary ray.

Still another aspect of the present invention provides
 the semiconductor laser module according to the above aspects,
 10 wherein surfaces where the first port and the second port
 of the polarization combining unit are formed inclined, so
 that the ordinary ray propagates in the direction of the
 axis line of the optical fiber.

Still another aspect of the present invention provides
 15 the semiconductor laser module according to the above aspects,
 wherein the semiconductor laser element, and the first lens
 are arranged to be inclined by a predetermined angle to the
 direction of the axis line, so that the ordinary ray
 propagates in the direction of the axis line of the optical
 20 fiber.

According to still another aspect of the present
 invention provides the semiconductor laser module according
 to the above aspects, wherein the polarization rotating unit
 and the polarization combining unit are fixed to the same
 25 holder part.

Still another aspect of the present invention provides the semiconductor laser module according to the above aspects, wherein a prism, where the first laser beams and the second laser beams are entered, and emitted to make their optical axes substantially parallel to each other, is disposed
5 between the first lens and the polarization combining unit.

Still another aspect of the present invention provides the semiconductor laser module according to the above aspects, wherein the prism, the polarization rotating unit, and the
10 polarization combining unit are fixed to the same holder part.

Still another aspect of the present invention provides the semiconductor laser module according to the above aspects, wherein a second lens, which is disposed between the
15 polarization combining unit and the optical fiber, and by which laser beams emitted from the third port of the polarization combining unit are optically coupled to the optical fiber.

Still another aspect of the present invention provides
20 the semiconductor laser module according to the above aspects, wherein the first lens is positioned, so that the first laser beams and the second laser beams focus on focal points between the first lens and the second lens.

Still another aspect of the present invention provides
25 the semiconductor laser module according to the above aspects,

wherein an optical reflection section by which laser with a predetermined wavelength are feed-back to the semiconductor laser element.

Still another aspect of the present invention provides
5 the semiconductor laser module according to the above aspects, wherein the optical reflection section is a fiber grating formed in the optical fiber.

Still another aspect of the present invention provides the semiconductor laser module according to the above aspects,
10 wherein a cooling device which cools the semiconductor laser element; and a base which is fixed to the cooling device, and mounts the semiconductor laser element are provided, wherein the first lens, the polarization rotating unit and the polarization combining unit are fixed to the base.

15 Still another aspect of the present invention provides the semiconductor laser module according to the above aspects, wherein the base comprises: a first base which fixes the semiconductor laser element; and a second base which is fixed to the first base, and fixes the first lens, the polarization
20 rotating unit, and the polarization combining unit.

Still another aspect of the present invention provides the semiconductor laser module according to the above aspects, wherein a first step to fix the semiconductor laser element to a base; a second step to fix the first lens to the base
25 after centering in a state where laser beams are emitted

from the semiconductor laser element; a third step to fix the polarization rotating unit to the base after centering in a state where laser beams are emitted from the semiconductor laser element; a fourth step to fix the polarization combining unit to the base after centering in a state where laser beams are emitted from the semiconductor laser element; and a fifth step to fix the optical fiber after centering in a state where laser beams are emitted from the semiconductor laser element are included in the fabrication method of the above aspects.

Still another aspect of the present invention provides the fabrication method according to the above aspects, wherein the polarization rotating unit and the polarization combining unit are fixed to the same holder part, and the third step and the fourth step are performed at the same time by centering the holder part.

Still another aspect of the present invention provides the fabrication method according to the above aspects, wherein a prism, where the first laser beams and the second laser beams are entered, and emitted to make their optical axes substantially parallel to each other, is disposed between the first lens and the polarization combining unit; the prism, the polarization rotating unit, and the polarization combining unit are fixed to the same holder part; and the third step and the fourth step are performed

at the same time by centering the holder part.

Still another aspect of the present invention provides the fabrication method according to the above aspects, wherein centering the holder part comprises the following

5 steps: a step to emit laser beams from both the first stripe and the second stripe of the semiconductor laser element; a step to make the first laser beams emitted from the first stripe enter the first port of the polarization combining unit, and, at the same time to make the second laser beams

10 emitted from the second stripe enter the second port of the polarization combining unit; a step to adjust the position of the holder part by rotating it around a center axis so that the first laser beams which enter the first port, and the second laser beams which enter the second port are emitted

15 together from the third port; and a step to fix the position of the holder part around the center axis after the step of the position adjustment.

Still another aspect of the present invention provides the semiconductor laser module according to the above

20 aspects; wherein an amplifier for optical fiber comprises: the optical fiber on which signal beams are transmitted, wherein excitation beams emitted from the semiconductor laser module, and the signal beams transmitted on the optical fiber are multiplexed for giving gains to the signal beams.

25 Other objects and features of this invention will

become understood from the following description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a side sectional view which shows a configuration of a semiconductor laser module according to an embodiment 1 of the present invention;

Fig. 2 is an explanatory view which shows a schematic configuration of the semiconductor laser module according to the embodiment 1 of the present invention;

Fig. 3A is a side view which shows a configuration of a prism;

Fig. 3B is a plan view of the configuration of the prism;

15 Fig. 4A is a plan view which shows a holder fixing
the prism, a half-wave plate, and a polarization beam
combiner;

Fig. 4B is a side sectional view of the holder;

Fig. 4C is its front view of the holder;

20 Figs. 5A and B are explanatory views which explain
the centering process of a first lens;

Figs. 6A and B are explanatory views which explain a configuration of a semiconductor laser element;

Fig. 7 is a view which shows optical output power characteristics, and driving voltage characteristics to

drive currents with regards to a semiconductor laser element with a W stripe structure shown in Fig. 6, and a semiconductor laser element with a single stripe structure;

Fig. 8 is a view which shows wavelength variation characteristics to drive currents with regards to the semiconductor laser element with the W stripe structure shown in Fig. 6, and the semiconductor laser element with the single stripe structure;

Fig. 9 is a sectional view which shows another configuration of the semiconductor laser element;

Fig. 10 is a sectional view which shows further another configuration of the semiconductor laser element;

Fig. 11 is a perspective view which shows a configuration near the semiconductor laser element when CVD diamond is used as a heat sink;

Fig. 12 is a view which shows differences in the temperatures of an active layer when CVD diamond is and is not used;

Fig. 13 is an explanatory view which shows distances with regard to a first stripe and a second stripe;

Fig. 14 is a view which shows variations in the temperatures of an active layer according to variations in the distance between the active layers;

Fig. 15 is a view explaining the external appearance of the semiconductor laser module, and its module size;

Fig. 16 is a view which shows variations in the module size for the distance between the active layers;

Fig. 17 is an explanatory view which shows a schematic configuration of a semiconductor laser module according to
5 an embodiment 2 of the present invention;

Fig. 18 is an explanatory view which shows a schematic configuration of a semiconductor laser module according to an embodiment 3 of the present invention;

Fig. 19 is a block diagram which shows a configuration
10 of an amplifier for optical fiber according to an embodiment 4 of the present invention;

Fig. 20 is a view which shows a case when two stripes of the semiconductor laser element are formed inclined to each other; and

15 Fig. 21 is an explanatory view which explains a semiconductor laser device disclosed in the United States Patent Publication No. 5589684.

DETAILED DESCRIPTIONS

20 Hereinafter, preferred embodiments of a semiconductor laser element, a semiconductor laser module, and a fabrication method thereof, and an amplifier for optical fiber according to the present invention will be explained, referring to drawings.

25 In the first place, an embodiment 1 of the present

invention will be explained. Fig. 1 is a side sectional view which shows a configuration of a semiconductor laser module according to an embodiment 5, and Fig. 2 is an explanatory view which shows a schematic configuration of the semiconductor laser module according to the embodiment 1 of the present invention.

As shown in Fig. 1, a semiconductor laser module M1 according to the embodiment 1 comprises: a package 1 with a hermetically sealed inside; a semiconductor laser element 2 which is installed in the package 1, and emits laser beams; a photodiode 3; a first lens 4; a prism 5; a half-wave plate (polarization rotating unit) 6; a polarization beam combiner (PBC) 7; and an optical fiber 8.

The semiconductor laser element 2 comprises a first stripe 9 and a second stripe 10 which are longitudinally arranged in parallel with each other at a distance on the same plane as shown in Fig. 2, and emits a first laser beams K1 and a second laser beams K2 from the end surfaces of the first stripe 9 and the second stripe 10. K1 and K2 shown in Fig. 2 indicate trajectories of centers of the beams emitted from the first and second stripes 9 and 10, respectively. The laser beams are propagated with a certain degree of broadening around the centers as shown with dashed lines in Fig. 2. The distance between the first and second stripes 9 and 10 is, for example, approximately 40 μ m.

5. The photodiode 3 receives laser beams to monitor, which have been emitted from the end surface 2b at the rear side of the semiconductor laser element 2 (the left side in Fig. 1). The photodiode 3 is fixed and mounted on a photodiode carrier 12.

10 The first lens 4 has a function by which the first
laser beams K1 and the second laser beams K2, which have
been emitted from the end surface 2a at the front side of
the semiconductor laser element 2 (the right side in Fig.
1), enter the first lens and the beams are focused onto
15 different focusing positions (F1, F2), respectively, so that
the distance between the two laser beams K1 and K2 is
broadened.

The first lens 4 is held with a first lens-holding part 13. The first lens 4 is preferably positioned, so that an optical axis of the first laser beams K1 emitted from the first stripe 9 and an optical axis of the second laser beams K2 emitted from the second stripe 10 are substantially in symmetry with respect to the central axis of the first lens 4. Thereby, there is less disorder in the wave front of the laser beams and optical coupling efficiency to the

optical fiber 8 is improved as both the first laser beams K1 and the second laser beams K2 pass through an area with small aberration near the central axis of the first lens 4. As a result, the semiconductor laser module M1 with higher output power may be obtained. Here, the first lens 4 preferably uses an aspherical lens with small spherical aberration and with high coupling efficiency to the optical fiber 8 in order to control the effects of the spherical aberration.

10 The prism 5 is disposed between the first lens 4 and the polarization beam combiner 7, and emits the first laser beams K1 and the second laser beams K2, and makes their optical axes parallel to each other. The prism 5 is made of optical glass such as BX7 (borosilicate crown glass). The optical
15 axes of the first and second laser beams K1 and K2 which propagate not in parallel to each other from the first lens 4 are made parallel to each other by refraction at the prism 5. Thus the polarization beam combiner 7 arranged behind the prism 5 may be easily made, and at the same time the
20 size of the polarization beam combiner 7 may be made smaller to obtain the smaller semiconductor laser module M1.

Fig. 3A is a side view which shows a configuration of the prism 5, and Fig. 3B is a plan view of the configuration. As shown in Fig. 3, the prism 5 comprises an entry face 5a
25 which is formed flat, and an emitting face 5b with an

inclination of a predetermined angle θ . For example, the overall length L_1 of the prism 5 becomes approximately 1.0mm, and the predetermined angle θ is 3.2 ± 0.1 degrees, when the prism 5 is made of BK7, the distance between each of the stripes 9 and 10 of the semiconductor laser element 2 is $40\mu\text{m}$, and the first lens 4 with a focal length of 0.7mm is used.

Only the first laser beams K_1 of the first laser beams K_1 and the second laser beams K_2 which have passed the prism 5 enter the half-wave plate 6 where the plane of polarization of the entered first laser beams K_1 is rotated 90 degrees.

The polarization beam combiner 7 comprises: a first port 7a where the first laser beams K_1 enter; a second port 7b where the second laser beams K_2 enter; and a third port 7c where the first laser beams K_1 entered from the first port 7a and the second laser beams K_2 entered from the second port 7b are multiplexed and emitted. The polarization beam combiner 7 is, for example, a birefringent element by which the first laser beams K_1 propagate to the third port 7c as an ordinary ray, and the second laser beams K_2 propagate to the third port 7c as an extraordinary ray. When the polarization beam combiner 7 is a birefringent element, it is made of, for example, TiO_2 (rutile) so that the birefringence is high, and the separation width between the laser beams is large.

In the embodiment 1, the prism 5, the half-wave plate 6, and, the polarization beam combiner 7 are fixed to the same holder part 14. Fig. 4A is a plan view which shows the holder part 14 which fixes the prism 5, the half-wave plate 6, and the polarization beam combiner 7. Fig. 4B is its side sectional view thereof, and Fig. 4C is its front view. As shown in Figs. 4A through 4C, the holder part 14 is made of a material (for example, SUS403, 304, and so on) with a weldable quality for YAG laser beam welding; its overall length L2 is approximately 7.0mm, and its shape is generally formed substantially in a cylindrical shape. The prism 5, the half-wave plate 6, and the polarization beam combiner 7 are fixed respectively into a receiving section 14a formed in the inside of the holder part 14. The top section of the holder part 14 is opened, and its bottom section has a flat configuration.

Thereby, adjustment of coordinates of the prism 5 and around a center axis C1 of the polarization beam combiner 7 becomes very easy so that both the first laser beams K1 entered from the first port 7a of the polarization beam combiner 7, and the second laser beams K2 entered from the second port 7b are emitted from the third port 7c.

The optical fiber 8 receives laser beams emitted from the third port 7c of the polarization beam combiner 7 to transmit them to the outside. As shown in Fig. 2, an optical

reflection section 15 made of a fiber grating to reflect beams with a predetermined wavelength band is provided in the optical fiber 8. According to the optical reflection section 15, beams with a predetermined wavelength are feed-backed to the semiconductor laser element 2 which fixes the oscillation wavelength and, at the same time, to narrow the oscillation spectrum width of the semiconductor laser element 2. Then, the loss in the wavelength multiplexing division coupler (WDM) may be controlled low, and multiplexed beams with higher output power may be obtained when output beams from the semiconductor laser module M1 are multiplexed by a wavelength division multiplexing coupler for use as an excitation beam source of an erbium-doped amplifier for optical fiber or a Raman amplifier. At the same time, fluctuations in the gain of Raman amplification may be controlled when the output beams are used for the Raman amplification. The optical reflection section 15 is formed by causing periodical variations in the refractive index, for example, through irradiating ultraviolet beams, which have been in an interference fringe state, onto the core section of the optical fiber 8 via a phase mask.

A second lens 16 by which laser beams emitted from the third port 7c of the polarization beam combiner 7 are configured to be optically coupled to the optical fiber 8 is disposed between the polarization beam combiner 7 and

The first lens-holding part 13 which fixes the first lens 4, and the holder part 14 which fixes the prism 5, the half-wave plate 6 and the polarization beam combiner 7 are fixed by YAG laser beam welding on a second base 18 through a first supporting part 19a and a second supporting part 19b, respectively. Therefore, the second base 18 is preferably made of stainless steel and so on, which has good weldability. Further, the second base 18 is silver-soldered on the flat section 17a of the first base 17.

10 A cooling device 20 comprising a Peltier element is provided under the first base 17. Temperature increase by heat generation from the semiconductor laser element 2 is detected by a thermistor 20a provided on the chip carrier 11, and the cooling device 20 is controlled to keep the temperature detected by the thermistor 20a at constant. .
15 Thereby, the laser output of the semiconductor laser element 2 may be made high-powered and stabilized.

A window section 1b, which beams that pass through the polarization beam combiner 7 enter, is provided in the inside of a flange section 1a formed in the side section of the package 1, and an intermediate part 1d is fixed at the end surface of the flange section 1a. A second lens-holding part 21 which holds the second lens 16 to focus laser beams is fixed inside of the intermediate part 1d by YAG laser beam welding. A metal slide ring 22 is fixed at
20
25

beams K1 entered from the first port 7a, and the second laser beams K2 done from the second port 7b are multiplexed to be emitted from the third port 7c.

The laser beams emitted from the polarization beam combiner 7 are focused by the second lens 16 and enter the end surface of the optical fiber 8 held by the ferrule 23 for transmission to the outside. And, a part of the laser beams are reflected by the optical reflection section 15 of the optical fiber 8. Then, the reflected beams are feed-back to the semiconductor laser element 2 to form an external resonator between the semiconductor laser element 2 and the optical reflection section 15, and, then, laser beam oscillation at a wavelength band decided by the optical reflection section 15 may be realized.

On the other hand, the laser beams, which monitors, emitted from the end surface 2b at the rear side of the semiconductor laser element 2 are received by the photodiode 3, and the beam output power and so on of the semiconductor laser element 2 are adjusted by calculation of amounts of received beams of the photodiode 3.

In the semiconductor laser module M1 according to this embodiment 1, the first laser beams K1 and the second laser beams K2 are emitted from the semiconductor laser element 2; the plane of the polarization of the first laser beams K1 is rotated by 90 degrees with the half-wave plate 6; and

polarization combining of the first laser beams K1 and the second laser beams K2 is performed by the polarization beam combiner 7. Therefore, laser beams with higher output power and small degrees of polarization may be output from the optical fiber 8. And, laser beams with a fixed wavelength may be output from the optical fiber 8, as the optical reflection section 15 made of the fiber grating is provided in the optical fiber 8. Accordingly, the semiconductor laser module M1 may be applied as an excitation beam source of an erbium-doped amplifier for optical fiber which requires higher output power, or as a Raman amplifier which requires low polarization-dependence and wavelength stability.

And, time to position of the semiconductor laser element 2 is reduced, as only one semiconductor laser element provided with two stripes to emit two laser beams is used. Therefore, time to fabricate the semiconductor laser module M1 may be reduced.

Moreover, according to the configuration of this embodiment 1, the intensity of the beams output from the optical fiber 8 may be stabilized by controlling the influence of the warp of the package only in one direction, as two beams output from one semiconductor laser element are propagated substantially in the same direction, though variations, which are caused by the changes in the environmental temperatures and so on, in the power of the

output beams depending on the warp of the package have not been able to be controlled, unless the design of the semiconductor laser module is made with consideration with the warp of the package in respective axial directions, as
 5 beams have been conventionally emitted in completely different axial directions from two semiconductor laser elements.

Further, these two beams changes with the same tendency as that of the coupling efficiency to the optical fiber 8
 10 for the warp of the package and so on, as two beams are output from one semiconductor laser element. Accordingly, degrees of polarization of beams output from the optical fiber 8 are stabilized even when there are temperature fluctuations and so on.

15 Then, a fabrication method of the semiconductor laser module M1 according to the embodiment 1 of the present invention will be explained. In the first place, the second base 18 is silver-soldered and fixed on the flat section 17a of the first base 17.

20 Subsequently, the chip carrier 11 which fixes the semiconductor laser element 2, and the photodiode carrier 12 which fixes the photodiode 3 are soldered and fixed on the first base 17.

Then, the first lens 4 is fixed on the second base
 25 18 after centering. In the centering process of the first

lens 4, the first laser beams K1 and the second laser beams K2 are configured to be emitted from both the first stripe 9 and the second stripe 10 of the semiconductor laser element 2 by supplying a current to the semiconductor laser element 2. Thereafter, the first lens 4 is inserted after the emission direction is set as a reference direction, and the coordinates in the X, Y, and Z axis directions are decided.

Fig. 5 is an explanatory view which explains the centering process of the first lens. The coordinate in the direction of the X axis is decided, so that an angle θ_1 between the set reference direction (the center axis C2) and the first laser beams K1 is equal to an angle θ_2 between the center axis C2 and the laser beams K2, as shown in Fig. 5A. The coordinate in the Y axis direction is decided, so that the first laser beams K1 and the second laser beams K2 pass through the center of the first lens 4, as shown in Fig. 5B. The coordinate in the Z axis is decided, so that the spot of the laser beams becomes the minimum at a predetermined distance from the semiconductor laser element 2. The first lens-holding part 13 which holds the first lens 4 is fixed at the coordinates decided in the centering process on the second base 18 through the first supporting part 19a by YAG laser beam welding.

Subsequently, the holder part 14 which integrates the prism 5, the half-wave plate 6, and the polarization beam

combiner 7 is fixed on the second base 18 after centering. In the centering process of the holder part 14, θ around the center axis C1 (Refer to Fig. 4) of the holder part 14, and the coordinates in the X, Y, and Z axis directions are decided, using an optical fiber collimator for position alignment, so that the intensity of the beams coupled to the fiber become the maximum. In the positioning around the center axis C1 of the holder part 14, the coordinates are adjusted by rotating the holder part 14 around the center axis C1 so that both the first laser beams K1 entering the first port 7a, and the second laser beams K2 entering the second port 7b are emitted from the third port 7c. The holder part 14 is fixed at the coordinates decided in the centering process on the second base 18 through the second supporting part 19b by YAG laser beam welding.

Thereafter, the first base 17 is fixed on the cooling device 20 previously fixed on the bottom plate of the package 1 by soldering.

Subsequently, the semiconductor laser element 2 and the photodiode 3 which monitors is electrically connected to a lead of the package 1 (not shown) through gold wire (not shown).

Then, hermetical sealing is performed by resistance welding of the surrounding sections in an atmosphere of inert gas (for example, N_2 , and Xe) under putting a cover 1c on

top of the package 1.

Thereafter, the second lens 16 is fixed to the flange section 1a of the package 1 under centering on the XY plane and in the Z axis direction. In the process, the second
 5 lens 16 is fixed at a position by YAG laser beam welding so that the emitted beams is parallel to the center axis of the flange section 1a of the package 1.

Finally, the optical fiber 8 is fixed after centering. In this process, the metal slide ring 22 is fixed at the
 10 end portion of the second lens-holding part 21. The slide ring 22 is fixed at the end surface of the second lens-holding part 21 by YAG laser beam welding of both of the boundary sections after adjusting the positions in a plane (XY plane) perpendicular to the optical axis of the optical fiber 8.
 15 The ferrule 23 which holds the optical fiber 8 is fixed at a position, where the output power of the optical fiber 8 is the maximum, inside of the slide ring 22 by YAG laser beam welding. Thereby, the coordinate in the direction of the optical axis of the optical fiber 8 (in the Z axis
 20 direction) is fixed.

Here, the semiconductor laser element 2 which is used for the semiconductor laser module in this embodiment 1 will be explained. Fig. 6 is an explanatory view which explains a configuration of the semiconductor laser element 2 used
 25 for the semiconductor laser module according to the

embodiment 1 of the present invention. Here, Fig. 6B is a sectional view taken on the a-a line in Fig. 6A.

As shown in Fig. 6A, the semiconductor laser element 2 has a configuration where epitaxial growth of a predetermined semiconductor is performed on a substrate 24 by a well-known epitaxial growth method such as the organometallic vapor phase growth method, the liquid phase growth method, the molecular beam epitaxial growth method, and the gas-source molecular beam epitaxial growth method and so on to form a laminated structure 25 to be explained later; thereafter, a lower electrode 26 is formed under the bottom of the substrate 24, and an upper electrode 27 is formed on the laminated structure 25; a predetermined resonator length L3 is obtained after cleavage; and a low reflection film 28 is deposited onto one plane of cleavage (front end plane 2a), and a high reflection film 29 is deposited onto the other plane of cleavage (rear end plane 2b).

As shown in Fig. 6B, the laminated structure 25 on the substrate 24 has, for example, an embedded type BH (Buried Heterostructure) structure, wherein a lower clad layer 31 which comprises, for example, n-InP; an active layer 32 with a GRIN-SCH-MQW (Graded Index Separate Confinement Heterostructure Multi Quantum Well) structure which comprises, for example, a multilayer of GaInAsP; and an upper clad layer

33 which comprises, for example, p-InP are laminated one after another on the substrate 24 which comprises, for example, n-InP, and in addition, an upper embedded layer 34 which comprises, for example, p-InP; and a cap layers 5 35 which comprises, for example, p-GaInAsP are laminated on the upper clad layer 33. Then, the upper electrode 27 is formed on the cap layer 35, and the lower electrode 26 is formed on the bottom surface of the substrate 24.

Then, the lower clad layer 31, the active layer 32, 10 and the upper clad layer 33 are processed like two stripes (the first stripe 9 and the second stripe 10) parallel to each other at a distance of 40 to 60 μ m, and a narrow section for current injection into the active layer 32 is formed to the side by laminating of, for example, the p-InP layer 15 36, and n-InP layer 37 in this order.

It is preferable from a view point of higher output power that the active layer 32 has a compressive strain quantum well structure with a lattice mismatch ratio of 0.5% or more, and 1.5% or less, and, uses a multiquantum well 20 structure with a well number of approximately 5. And, as lattice matching requirements are equivalently met when a barrier layer has a strain compensation structure which introduces tensile strains opposite to the strains of the well layer as the strain quantum well structure, there is 25 no need to set an upper bound for the lattice mismatch ratio

of the well layer. Moreover, the width of the active layer
 32 formed like the stripes has been assumed to be
 approximately 2.5 to 3 μ m from a view point to reduce the
 electrical resistance, and have transverse single mode
 5 oscillation. In addition, though the width of the active
 layer to cut off transverse higher mode, and single mode
 depends on the design of the wave guide, it is preferable
 from a view point of higher output power to form the stripe
 widths a little bit smaller than the cut off one.

10 Then, a fabrication method of the semiconductor laser
 element 2 will be explained. In the first place, layers
 are laminated on the substrate 24 in order of the lower clad
 layer 31, the active layer 32 with the GRIN-SCH-MQW structure,
 and the upper clad layer 33 by a well-known epitaxial growth
 15 method such as the organometallic vapor phase growth method,
 the liquid phase growth method, the molecular beam epitaxial
 growth method, the gas-source molecular beam epitaxial
 growth method and so on.

Then, two masks parallel to each other at a distance
 20 of 40 to 60 μ m apart are formed on the upper clad layer 33;
 the upper clad layer 33, the active layer 32, and a part
 of the lower clad layer 31 is dissolved, by using a
 predetermined etchant; and the narrow section for current
 injection into the active layer 32 is formed by further
 25 laminating of the p-InP layer 36 and the n-InP layer 37 onto

the stripe side section in this order.

Subsequently, epitaxial growth of the upper embedded layer 34 comprising p-InP, and the cap layer 35 comprising p-InGaAsP is performed for laminating.

5 Thereafter, the upper electrode 27 is formed on the cap layer 35, and the lower electrode 26 is formed on the bottom of the substrate 24.

Then, the predetermined resonator length L3 is obtained after cleavage; and, further, the low reflection
10 film 28 is deposited onto the one plane of cleavage (front end plane 2a), and the high reflection film 29 is deposited onto the other plane of cleavage (rear end plane 2b).

The semiconductor laser element 2 made as above is bonded to the not shown heat sink at the side of the upper
15 electrode 27, by using AuSn soldering and so on. And, simultaneous laser oscillation of two stripes are occurred as the current is supplied to the stripes from the outside through the upper electrode 27 (the p side in this embodiment 1) and the lower electrode 26 (the n side in this embodiment
20 1), and two output beams from the low reflection film 28 are multiplexed by the polarization beam combiner 7 for a required use.

Here, the threshold current of the semiconductor laser element 2 according to this embodiment 1 shows twice that
25 of one stripe, and total output power becomes twice the

optical output power of one stripe, if two stripes 9 and 10 have exactly the same characteristics. That is, approximately twice the optical output power is obtained at the semiconductor laser element 2 by approximately twice the driving current per one stripe as a whole, and the slope efficiency of the semiconductor laser element 2 is equivalent in that of the semiconductor laser element 2 with one stripe. Moreover, high coupling efficiency to single mode fibers may be obtained, by using an optical system to be explained later as the laser beams of each stripe 9 and 10 oscillates in a transverse single mode.

For example, Fig. 7 is a view which shows relations between the optical output power for the semiconductor laser element 2 with a W stripe structure which uses two stripes 9 and 10, and for the semiconductor laser element which uses the same one as that of the stripe 9 or 10, and the driving voltage. In Fig. 7, though the optical output power characteristics L_s to the driving currents by the semiconductor laser element which uses one stripe show a saturated state near at 1000mA of the driving currents, the optical output power characteristics L_w to the driving currents by the semiconductor laser element 2 with the W stripe structure show a saturated state near at 2000mA of the driving currents and substantially the same slope as that of the optical output power characteristics L_s to the

driving currents for the element using one stripe. As a result, the semiconductor laser element 2 with the W stripe structure may obtain twice the optical output power of the semiconductor laser element which uses one stripe. In the semiconductor laser module which uses the semiconductor laser element with the W stripe structure, a fiber end optical output power of approximately 570mW was obtained at 2400mA of the driving currents in a wavelength 1430nm band used for the Raman amplifier. Here, a fiber end optical output power of approximately 500mW may be obtained in a wavelength band from approximately 1200nm to approximately 1600nm.

Here, when the variations in the driving voltages V_w for the driving currents of the semiconductor laser element 2 with the W stripe structure, and the variations in the driving voltages V_s for the driving currents of the semiconductor laser element using one stripe are compared, the variations V_w in the driving voltages of the W stripe structured one are approximately half of the variations V_s in the driving voltages of the one stripe structured one. The reason is because areas into which the driving currents are injected with case of the W stripe structured one are twice those of the one stripe structured one. As a result, the driving electric power of the semiconductor laser element, that is, the conversion efficiency of the optical output power for the driving currents X voltages for the W stripe

structured one is improved in comparison with that of the single stripe structured one.

Moreover, the driving currents per one strip is a half of the total currents when it is the W stripe structured.

5 The effects of the heat between both stripes are controlled very small by choosing a stripe distance of 40 to 60 μ m, and the temperatures in the active layer substantially equal to those of the single stripe structured one may be obtained.

The current dependence of the oscillation wavelength
10 of the laser beams is decided mainly by the heat in the active layer caused by the reactive power, and variations in the refractive index caused by the heat. Therefore, for example, the value of the variations in the wavelength λ_w when the driving currents of the semiconductor laser element with
15 the W stripe structure are raised from 100mA to 1000mA is approximately equal to the value of the variations in the wavelength λ_s when the driving currents of the semiconductor laser element with the single stripe structure are raised from 50mA to 500mA, and, then, as shown in Fig. 8, the stability
20 in the wavelength will be improved approximately twice.

Here, though a structure where two stripes are driven at the same time had been shown in the examples explained above, for example, a separation trench 38 reaching the bottom of the active layer 32 from the upper electrode 27
25 is formed between two stripes, as shown in Fig. 9, and two

stripes may be electrically separated by coating the surface of the separation trench 38 with an insulation film 39. When the side of the lower electrode 26 of such semiconductor laser element 2 is bonded to the not shown heat sink by AuSn soldering and so on, the driving currents supplied to two stripes may be independently controlled, and the plane of polarization of the laser beams output from the optical fiber 8 may be easily randomized.

Moreover, when the side of the upper electrode 27 is bonded to the not shown heat sink for use, these two stripes may be independently driven by forming an electrode pattern corresponding to the upper electrode 27 at the side of the heat sink.

In addition, though the semiconductor laser element 2 had been provided with the embedded InP type BH structure in the examples explained above, the laser element 2 may be, for example, of a GaAs ridge waveguide type as shown in Fig. 7. As shown in Fig. 10, an n type lower clad layer 41, an active layer 42, a p type upper clad layer 43, an insulation layer 44, and a p-GaAs layer 45 are laminated on the substrate 40 which comprises n-GaAs, and two ridge sections are formed in the semiconductor laser element 2. An upper electrode (p electrode) 46 is formed on the insulation layer 44 and the p-GaAs layer 45, and an lower electrode (n electrode) 47 is formed on the bottom surface

of the substrate 40.

Here, a configuration where a CVD diamond is used as the heat sink will be explained. Fig. 11 is a perspective view which shows the vicinity of the semiconductor laser element 2. In Fig. 11, the semiconductor laser element 2 and the thermistor 20a are bonded onto a CVD diamond 11a. Moreover, the bottom of the CVD diamond 11a is coupled to the heat sink 11b formed with AlN. And, a mount 17a formed with CuW corresponding to the first base 17 is bonded to the bottom of the heat sink 11b. The CVD diamond 11a and the heat sink 11b correspond to a chip carrier 11, and form two-stage heat sinks. As the CVD diamond 11a has high heat conductivity and non-conductivity, the heat generated in the semiconductor laser element 2 may be effectively discharged.

Fig. 12 is a view which compares temperatures of the active layer 32 and those of the upper section of the mount 17a when the temperature of the thermistor 21a is assumed to be 25°C for each case when the upper heat sink of two stage heat sinks is assumed to be made of the CVD diamond 11a and AlN. In Fig. 12, the temperatures of the active layer co is lower by approximately ten or so degrees, comparing the semiconductor laser element "A" (when the upper heat sink is assumed to be made of CVD diamond) with the semiconductor laser element "B" (when the upper heat sink

is assumed to be made of AlN). In this case, when variations in the temperatures of the active layer are small, the semiconductor laser element "A" which uses the CVD diamond 11a shows higher stability in the wavelength as explained above, as the variations in the refractive index caused become small.

Here, the distance between the first stripe 9 and the second stripe 10 will be discussed. Fig. 13 is a sectional view taken on the a-a line of the semiconductor laser element 2 in Fig. 6A in a similar manner to that of Fig. 6B. In Fig. 13, the distance between center lines in the active layers 32 is assumed to be " W_c "; the transverse line width of the active layers 32 is assumed to be " W_a "; and the distance between the insides of the active layer 32 is assumed to be " W_s ". Here, the line width W_a is assumed to be 2.5 to 3 μm , and the distance W_c is assumed to be 10 to 100 μm . Therefore, when the distance W_c is 10 μm , the distance W_s becomes 7 to 7.5 μm . Moreover, the relations show in connection with the line width W_a that the ratio of the distance W_s to the distance W_c is within a range of 0.7 to 0.97, and that the ratio of the distance W_c to the line width W_a is within a range of 2 to 40.

It has been assumed that the distance W_c is 10 to 100 μm , as too large distance W_c causes large distance between the center axes of each stripe 9 and 10 of the semiconductor

laser element 4 and the first lens 4; eclipse of the laser beams is caused around the periphery of the first lens 4; and then the coupling efficiency to the first lens 4 is reduced. And, another reason is that the coupling efficiency is
5 reduced by larger effects of the lens aberration caused when the laser beams enter around the periphery of the first lens 4.

On the other hand, further another reason is that too small distance W_c causes difficult forming of each stripe
10 9 and 10 including the active layer 32 by the current fine processing technologies; and difficult ridge forming and embedded growth of each stripe 9 and 10. And, another reason is that the laser beams output from each stripe 9 and 10 interfere each other. In addition, further another reason
15 is that generated heat in the active layer 32 is increased when stripes 9, 10 approach each other.

For example, Fig. 14 is a view which shows variations in the temperatures of the active layer 32 according to variations in the distance W_c of the semiconductor laser
20 element 2 which uses the CVD diamond 11a. As shown in Fig. 14, the smaller the distance W_c is, the larger the increase in the temperature of the active layer 32. And, when the distance W_c is larger than approximately 40 to 60 μm , the temperatures converge into an approximately constant
25 temperature, that is, nearly 38°C. Here, the result shown

in Fig. 14 is when the ambient temperature is controlled to be 25°C, and the temperature at the bottom of the mount 17a is controlled to be 25°C.

In addition, too small distance W_c causes the larger
5 module length of the semiconductor laser module M1. The reason is that the length of the optical path for separation of the laser beams from each stripe 9, and 10 becomes long by the first lens 4. Fig. 15 shows the external appearance of the semiconductor laser module M1. When the module size
10 of the semiconductor laser module with a shape shown in Fig. 15 is defined as the length "Lm" in the longitudinal direction of the cover as shown in Fig. 15, the module size Lm changes as shown in Fig. 16 according to the variations in the distance W_c . In Fig. 16, the module size Lm becomes 80mm, 40mm, 25mm,
15 and 20mm, respectively, at a distance W_c of 5 μ m, 10 μ m, 40 μ m, and 60 μ m in order of size; the module size Lm rapidly becomes small at a distance W_c of 20 μ m; and the module size Lm converges into approximately 20 μ m at a distance W_c of approximately 40 μ m to 60 μ m.

20 Therefore, the distance W_c is preferably 40 μ m to 60 μ m, considering the distance (W_c) dependence of the active layer temperatures shown in Fig. 14, and the distance (W_c) dependence of the module size shown in Fig. 16.

Moreover, the distance W_s between the insides of the
25 active layer 32 is preferably assumed to be 5 μ m or more.

need to dispose a prism 5 between a half-wave plate 6 and a first lens 4.

Moreover, it is possible to decrease the effects of the warp of a package on the optical output power characteristics in a high temperature state, as the length of the semiconductor laser module M2 in the direction of the optical axis may be reduced.

Here, the half-wave plate 6 and the polarization beam combiner 7 are preferably fixed to the same holder part 14 even in this embodiment 2 in order to facilitate the angle adjustment around a center axis.

Then, an embodiment 3 of the present invention will be explained. Fig. 18 is an explanatory view which shows a schematic configuration of a semiconductor laser module M3 according to the embodiment 3 of the present invention. In this embodiment 3, a semiconductor laser element 2 and a first lens 4 are arranged inclined by a predetermined angle to the direction of the axis line so that a first laser beams K1 which is an ordinary ray propagates in the direction of the axis line of an optical fiber 8. According to this embodiment 3, the configuration may be made easier, as the first laser beams K1 which is an ordinary ray propagates in the direction of the axis line of the optical fiber 8, and there is no need to dispose a prism 5 between a half-wave plate 6 and the first lens 4. Moreover, simplification in

smoothing and polishing of a polarization beam combiner 7 may become possible in comparison with those of the embodiment 2, as the smoothing and polishing are performed only for the one side.

Moreover, it is possible to decrease the effects of the warp of a package on the optical output power characteristics in a high temperature state, as the length of the semiconductor laser module M3 in the direction of the optical axis may be reduced.

10 Here, the half-wave plate 6 and the polarization beam
combiner 7 are preferably fixed to the same holder part 14
even in this embodiment 3 in order to facilitate the angle
adjustment around a center axis.

The semiconductor laser modules M1 to M3 shown in the
15 embodiments 1 to 3 may be used as an excitation beam source
of an erbium-doped amplifier for optical fiber, or a Raman
amplifier, as laser beams with higher output power, small
degrees of polarization, and a stable wavelength may be
output.

20 Then, an embodiment 4 of the present invention will
be explained.. Fig. 19 is a block diagram which shows a
configuration of an amplifier for optical fiber according
to the embodiment 4 of the present invention. As shown in
Fig. 19, an amplifier for optical fiber 48 according to the
25 embodiment 4 of the present invention comprises: an input

section 49 where signal beams are input; an output section 50 where signal beams are output; an optical fiber 51 (fibers for amplification) which transmits the signal beams between the input section 49 and output section 50; an excitation beam generation section 52 where excitation beams are generated; and a WDM coupler 53 which multiplexes excitation beams generated by the excitation beam generation section 52, and signal beams which are transmitted to the optical fiber 51 (fiber for amplification). Optical isolators 54 through which only signal beams in the direction from the input section 49 to the output section 50 may transmit are provided between the input section 49 and the WDM coupler 53, and between the output section 50 and the WDM coupler 53, respectively.

15 The excitation beam generation section 52 comprises: a plurality of semiconductor laser modules M, which emit laser beams with different wavelength bands from each other, according to the embodiments 1 to 3 of the present invention; and a WDM coupler 55 which combines the laser beams emitted from the semiconductor laser module M.

20 The excitation beams emitted from the semiconductor laser module M are combined by the WDM coupler 55 to obtain output beams of the excitation beam generation section 52.

25 The excitation beams generated in the excitation beam generation section 52 is coupled to the optical fiber 51

by the WDM coupler 53, and, on the other hand, the signal beams input from the input section 49 are multiplexed with the excitation beams in the optical fiber 51; amplified; made pass through the WDM coupler 53; and output from the output section 50.

The present invention is not limited to the embodiments 1 to 4, and variations may be executed within the scope of the technical matters described in the claims.

Though the first stripe 9 and the second stripe 10 of the semiconductor laser element 2 are formed, to extend in the longitudinal direction parallel to each other, they should not be limited to the above, and may be formed inclined, for example, as shown in Fig. 20. In this case, the length of the semiconductor laser module M in the direction of the optical axis may be shortened as two laser beams emitted from two stripes 9 and 10 cross each other at a point in a short distance from the semiconductor laser element 2, and the propagation distance (L in Fig. 2) required enough to separate them (that is, D' becomes sufficiently large in Fig. 2) is reduced, so that the half-wave plate 6 may be inserted only on the optical path of the first laser beams K1 after the first laser beams K1, and the second laser beams K2 have passed the first lens 4. Though the distance Wc between stripes 9 and 10 has the maximum and the minimum values in this case, any of both the values is preferably

semiconductor substrate; and the second stripe emitting the second laser beams in the second active layer laminated in the other part of the area of the semiconductor substrate; the optical output power characteristics with approximately
5 twice the optical output power in comparison with that of the semiconductor laser element with one stripe may be obtained, and the series resistance may be reduced approximately by half. Moreover, the electric power consumption per optical output power may be decreased in
10 comparison with that of the one stripe type, that is, the single stripe type, and, at the same time, the maximum optical output power may be approximately doubled, as the driving voltage may be decreased. In this case, reductions in the coupling efficiency around the periphery of the first lens
15 caused by eclipse of the laser beams, and the reductions in the coupling efficiency depending on the effects of the lens aberration may be controlled by assuming that the distance between the center lines of the first stripe and the second stripe is $100\mu\text{m}$ or less. In addition, the
20 wavelength stability is maintained, and, the size of the semiconductor laser module can be minimized, as rise in the temperatures of the active layers is suppressed by assuming that the distance between the centers is $10\mu\text{m}$ or more. Moreover, interference between the laser beams which
25 leak from each stripe may be prevented by assuming that the

element and the first lens is reduced, as only one semiconductor laser element provided with two stripes to emit two laser beams, and one first lens are used. Therefore, time for fabrication of the semiconductor laser module may
5 be reduced.

Moreover, according to the present invention, the intensity of the beams output from the optical fiber may be stabilized by controlling the effects of the warp of the package only in one direction, as two beams output from one
10 semiconductor laser element are propagated substantially in the same direction, though variations, which are caused by environmental temperatures and so on, in the power of the output beams depending on the warp of the package have not been able to be controlled, unless the design of the
15 semiconductor laser module is made considering the warp of the package in respective axial directions, as beams have been conventionally emitted in completely different axial directions from two semiconductor laser elements.

And, these two beams changes with the same tendency
20 as that of the coupling efficiency to the optical fiber for the warp of the package and so on, as two beams are output from one semiconductor laser element. Accordingly, degrees of polarization of beams output from the optical fiber are stabilized even when there is temperature fluctuations and
25 so on.

In order that the present invention is completely and explicitly disclosed, typical embodiments have been described.

However, the appended claims should not be limited
 5 to the embodiments, and ought to be interpreted, so that any modifications and alternative configurations which those skilled in the art might create are realized within the essential matters shown in the present specification.

Although the invention has been described with respect
 10 to a specific embodiment for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art which fairly fall within the basic teaching herein set forth.

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